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"CHEMICAL BEAM EPITAXY OF ZnSe"

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Work by Leslie Kolodziejski and her collaborators is summarized here.

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OBJECTIVE

The objective of the program is to determine optimum growth parameters for the chemical beam epitaxy of ZnSe. In addition microstructural, optical, and electrical characterization of the material will be performed to assess the material's quality and potential; comparisons will be made with material grown by molecular beam epitaxy. Zinc Selenides,

PROGRESS

During the initial period of the award, the extensive hardware necessary to fabricate the material was not available. At this time a multiple chamber chemical beam epitaxy (CBE) facility is being assembled by EMCORE Corporation and is scheduled for delivery in mid August 1989. In addition to the growth chamber, the system has i) an introduction chamber capable of accepting five separate 2" wafers, ii) a bakeout chamber required to clean the sample holders prior to mounting the substrate, and iii) an ultrahigh vacuum transfer module containing a high temperature stage for outgassing substrates and an elevator for multiple wafer storage. Figure 1 is a schematic drawing of the CBE system. The entire system will be computer controlled via a sophisticated MASSCOMP computer complete with customized software. The transfer module has additional porting such that three separate UHV chambers may be added in the future; the expansion could include growth chambers, a metalization chamber, or other in situ processing chambers. An equipment proposal is currently under review by the National Science Foundation which proposes the addition of an analytical chamber, having Auger electron spectroscopy (AES), with plans to add electron spectroscopy for chemical analyis (ESCA) in the near future.

The CBE growth chamber is equipped with four individual gas injectors for metalorganics of Zn, Ga, and Se, and for arsine, as well as with three typical MBE-like effusion cells which can be used for dopants or alloying elements. (Each gas injector has the capability of accepting six separate gases.) In situ analysis facilities include reflection high energy electron diffraction, a residual gas analyzer, a quartz crystal flux monitor, and additional heated, quartz viewports, placed in such a manner that a laser beam can be both incident to, and reflected from, the growing surface front. As an extra safety precaution, the entire growth chamber, pumping system and gas manifold panel is housed in a fully exhausted, laminar flow bench, providing a 'clean room' environment for the CBE facility. The introduction chamber will also be located in an exhausted, laminar flow hood to minimize any contamination from the laboratory and to protect the samples both before and after growth.

A 1200 sq. ft. laboratory will house the epitaxy facility and is currently in preparation at MIT. Plans for the laboratory include i) a changing room to keep the environment relatively clean,

ii) two 8 ft exhausted, laminar flow hoods for acids and solvents to chemically prepare the substrates, iii) a laminar flow bench to store ultrahigh vacuum hardware, iv) a Nomarski interference microscope to monitor surface morphology, v) an Apple computer for data storage of all samples analyzed, and vi) a surface profilometer to measure the layer thickness. Also available is a Spectra Physics argon ion laser, complete with heat exchanger, to perform visible and ultraviolet laser-assisted epitaxial growth experiments. The Electrical Engineering Department has volunteered to hire a full time dedicated engineer to maintain, service, and repair the new CBE facility. With the hiring of such personnel, an excellent opportunity will be available for apprenticeship, as EMCORE is locating one of their engineers, who is participating in the assembly of the CBE, at MIT for six months after delivery and installation of the CBE system.

Upon receipt of the epitaxy hardware, experiments will be underway to begin testing procedures of the specially designed, one-of-a-kind instrument to familiarize the research team with the operation of the machine. Following the initial training period experiments will commence in the chemical beam epitaxy of ZnSe using metalorganics of Zn and Se. The use of both visible and ultraviolet laser illumination will be implemented to assist in the growth. Ga and arsine will also be available initially for n- and p-type dopants, in addition to the use of In, Ga, and arsine for the growth of lattice matched buffer layers of InGaAs to ZnSe, all grown on GaAs substrates.

PUBLICATIONS

a. Papers Submitted to Referred Journals (and not yet published)

- Q. D. Qian, J. Qiu, M. R. Melloch, J. A. Cooper, Jr., R. L. Gunshor, and L. A. Kolodziejski, "Electrical Characterization of the Epitaxial ZnSe/ Epitaxial GaAs Interface," *Applied Physics Letters*, 13 April 1989 issue. (Supported by Office of Naval Research, Defense Advanced Research Projects Agency)

b. Papers Published in Referred Journals

- R. L. Gunshor and L. A. Kolodziejski, "Recent Advances in the Molecular Beam Epitaxy of ZnSe and its Superlattices (INVITED)," *IEEE Trans. on Quantum Electronics, Special Issue on Quantum Well Heterostructures and Superlattices* vol. QE-24(8), pp. 1744-1757, 1988. (Supported by Office of Naval Research, Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, and National Science Foundation)

c. Books (and sections thereof) Submitted for Publication

• L. A. Kolodziejski, R. L. Gunshor, N. Otsuka, and A. V. Nurmikko, "MBE of Wide Bandgap II-VI Compound Semiconductor Superlattices and Diluted Magnetic Semiconductors," in: *Molecular Beam Epitaxy*, (eds. Robin F. C. Farrow and John R. Arthur), pp. xxx, 1989. (Supported by Office of Naval Research, Air Force Office of Scientific Research, and Defense Advanced Research Projects Agency)

• L. A. Kolodziejski, R. L. Gunshor, and A. V. Nurmikko, "II-VI Strained-layer Semiconductor Superlattices," in: *Strained Layer Superlattices*, (eds. Robert Biefeld) pp. xxx, 1989. (Supported By Office of Naval Research, Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, National Science Foundation, and Naval Research Laboratory)

g. Invited Presentations at Topical or Scientific/Technical Society Conferences

• R. L. Gunshor, L. A. Kolodziejski, and A. V. Nurmikko, "ZnSe/MnSe Magnetic Semiconductor Superlattice," presented at the *Warren E. Henry Sumposia on Magnetics*, Washington, D. C., August 1988.

• A. V. Nurmikko, R. L. Gunshor, and L. A. Kolodziejski, "Optical Characterization of Wide Bandgap II-VI Multiple Quantum Wells," presented at the *5th International Conference on Molecular Beam Epitaxy*, Sapporo, Japan, August, 1988.

• R. L. Gunshor, L. A. Kolodziejski, N. Otsuka, and A. V. Nurmikko, "II-VI/III-V Heterostructures," presented at the *Meeting of the Electrochemical Society*, Chicago, October, 1988.

• R. L. Gunshor, L. A. Kolodziejski, N. Otsuka, A. V. Nurmikko, and M. Kobayashi, "II-VI/III-V Heterostructures," presented at the *SPIE Conference on Monitoring and Control of Plasma-Enhanced Semiconductors*, Santa Clara, November, 1988.

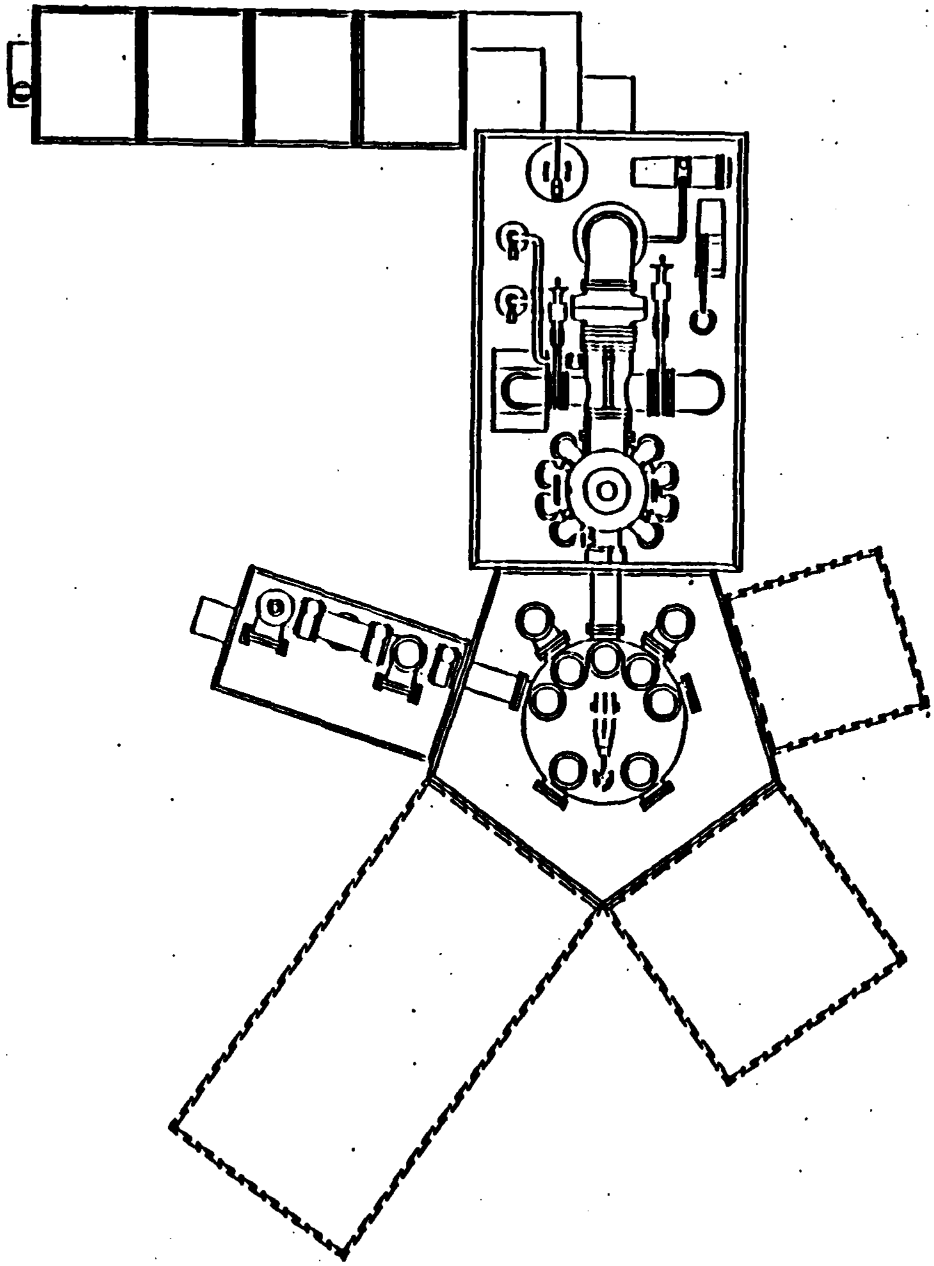

Figure 1: Schematic drawing of the layout of the chemical beam epitaxy system. The growth chamber, transfer module, and introduction chamber are shown with considerable detail, whereas the future expansion modules are only outlined. The approximate dimensions are 17 ft. x 25 ft.